ISSN 0704-3716

Canadian Translation of Fisheries and Aquatic Sciences

No. 5399

# Temporary operating instructions for the use of the instrument 'sonde-bathometer'

E. A. Sobchenko (ed.)

Original title: Unknown

Published by: State Oceanographical Institute, Odessa. 1976

Original language: Russian

Available from:
Canada Institute for Scientific and Technical Information
National Research Council
Ottawa, Ontario, Canada K1A 0S2

1988

26 typescript pages

## Preface

The instrument, "Sonde-Bathometer" was developed by the Central Construction Bureau of Hydrometeorological Instrument Construction (CCBHI) and is designed to measure temperature, electroconductivity, salinity and hydrostatic pressure. Trials were carried out on the weather ships of the State Oceanographic Institute, (S.O.I.), for the use of the instrument in scientific research. These tests show that the sonde can and should be introduced quickly into the general practice of oceanography.

These instructions come about with the aim of introducing the instrument into oceanographic research and depend on the tests conducted on the weather ships of the S.O.I. They are temporary in that, as the introduction of the instrument continues, they can be worked over and improved in the separate departments in which they are used.

## I. The Characteristics and Operating Conditions of the "Sonde-Bathometer"

The "sonde-bathometer" allows automatic measurement and recording of data pertaining to the distribution of temperatures and electroconductivity of seawater in the depths. The instrument also allows for the collection of a sample of seawater automatically at any given depth.

The sonde-bathometer can be used to carry out oceanological observations and can replace bathometric series to a depth of 2,000 m. and observational bathometers.

The complex, "sonde-bathometer", consists of three basic blocks:

1) A lowering assembly consisting of sensors and bottle sampling section
2) Cable winches for lowering and raising the assembly
3) The on-board apparatus

The lowering assembly is a metal pressure case with gauges installed on it to measure temperature, pressure and electroconductivity. Inside the case are the measurement section and the control section. The measurement section contains:

- -two serial pressure gauges: -DTM-25 for depths in the range 0-200 m.
  -MD-200T for depths in the range 200-2000 m.
- -series resistance thermometer ETS-2U
- -electroconductivity gauge consisting of two toroidally wound transformers aligned co-axially and inductively coupled through the conductive medium, seawater.

The power supply is on board the ship and is fed to the lowering assembly by a cable which at the same time serves to transmit control commands from the assembly.

The lowering assembly is also provided with a bottle sampling section with 18 bottles of type BM-48. It is also possible to attach reversing thermometer frame ROT-48.

Fig. 1 Block diagram of the instrument, "Sonde-Bathometer"

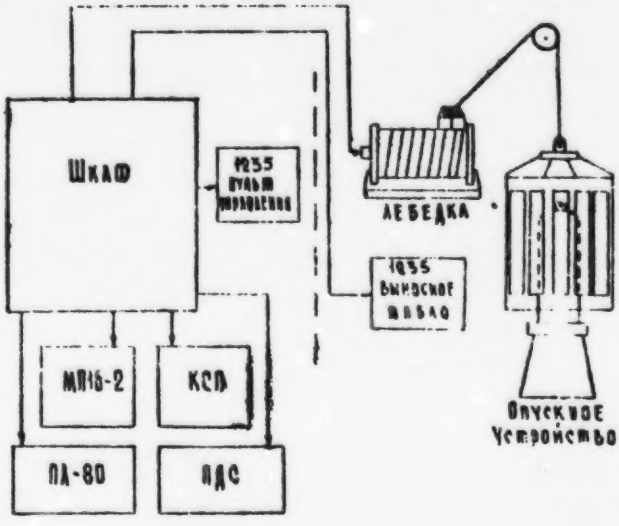


Table 1 is a summary of the technical characteristics of the instrument complex.

The cable hydraulic winch PR1266.00.0000 is used for lowering and raising the assembly. The winch is developed and prepared in S.E.K.B. Fisheries MRKh, USSR (Kaliningrad). It is provided with a control panel, means of elevation, has overall dimensions of 1415 x 1045 x 1160 mm, weighs without cable, 830 kg and with cable not more than 1430 kg. The winch is furnished with a single conductor "fisherman's cable" with a diameter of 55 mm,[a] and a length of 2000 m.

The second apparatus turns on the control panel and recording apparatus. From the control panel the task of operating the sounding is carried out. On the repeater panel of the central panel are digital representations of the readings of temperature, pressure, electroconductivity and the number of the sample bottle in operation. These data are transmitted simultaneously on an extension signal panel. The control panel is provided with: a) a receiver connected to the cable from the lowering assembly and (b) an instrument for conversion of received information into a code essential for recording on paper tape punch PL-80, printer PM-16-2, digital display, and two coordinate plotter PDS-021M.

a) Probably should read 5.5 mm - transl. note.

TABLE 1

Technical Characteristics of the Sonde-Bathometer

| | Parameters | Technical Characteristics |
|---|---|---|
| 1. | Temperature | |
| | Range of measurement | -2° - 32°C |
| | Sensitivity | 0.01°C |
| | Time constant | .4 sec. |
| | Basic root-mean-square error | ± .03°C |
| 2. | Electroconductivity | |
| | Range of measurement | $17 \cdot 10^{-3}$ - $71 \cdot 10^{-3}$ mho/cm |
| | Sensitivity | $.013 \cdot 10^{-3}$ mho/cm |
| | Limit (range) of error | ± $.04 \cdot 10^{-3}$ mho/cm |
| 3. | Salinity | |
| | Range of measurement | 17 - 39 °/$_{oo}$ |
| | Basic root-mean-square error of determination | ± .02 °/$_{oo}$ |
| 4. | Pressure | |
| | Range of measurement | 0-200 kgm/cm$^2$ |
| | Sensitivity | .02 kg/cm$^2$ for Range 1 |
| | Basic root-mean-square error | 1.5 kg/cm$^2$ for Range 2 |
| 5. | Duration of cycle | |
| | Measurement of three parameters | 0.6 s. |
| | Measurement of four parameters | 0.8 s. |
| | Power supply voltage | 220 v. |
| | Frequency | 50 Hz |
| | Power requirement | 150 watts |

The information enters from the lowered instrument in the form of an amplitude-modulated signal with a carrier frequency of the order of 11 KHz, and converts, depending on the output instrument, (a) in binary base 8 system code (on PL-80), (b) in decimal code (PM-16-2 and on the digital display), (c) a parallel binary code with subsequent conversion into analog voltage (PDS-021M).

The information is passed along in the form of a serial binary code. A full cycle of measurement is carried out in the following order: electroconductivity, temperature, pressure, number of sample bottle, or, only the first three parameters. The duration of the measurement is 0.8s (four parameters) or 0.6s (three parameters).

The lowering and raising of the container with the gauges (lowering assembly) is accomplished through an ordinary single-rail overhead travelling crane or derrick. For ease of use, it is recommended to install a movable overhead crane (Fig. 2) that will allow a decrease of the angles of inflection of the cable, and allow the easy withdrawal of the container onto the deck. With such securing of the container, the safety of the work is assured along with that of the working personnel (the preparation for lowering, the trouble shooting, taking of samples, etc.).

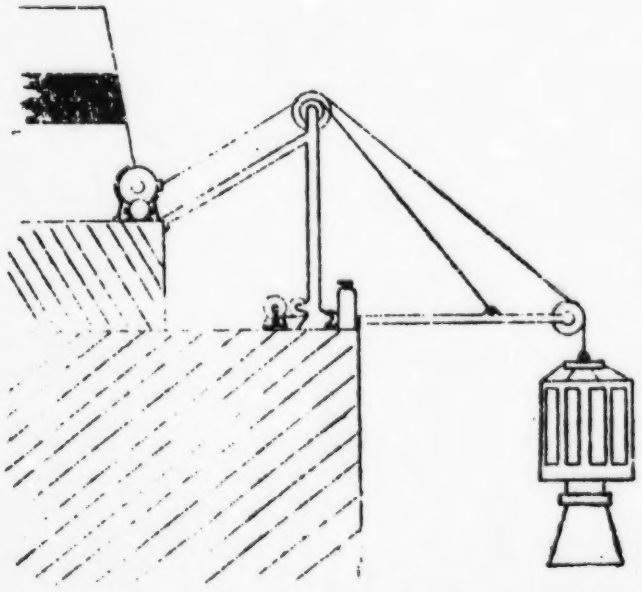

Fig. 2 Scheme of securing of lowering device, "Sonde-Bathometer"

Deep water sounding by means of the complex is accomplished at speeds of 0.2-1.0 m/sec. depending on layering of water masses. In this case, the recording of parameters of the medium is carried out at the time of lowering with the taking of the water sample for subsequent chemical analysis

accomplished while raising. The taking of a sample for performing calibration of the gauges is carried out while the sonde pauses at the sampling level (5 - 7 minutes).

When working with this instrument one must be guided by the following documents:

- -a technical description of the complex "sonde-bathometer"
- -instructions for using the complex "sonde-bathometer"
- -data sheet ETS-2U PS. A technical description and instructions for using ETS-2U PTO
- -data sheet for the pressure gauge for increased resolution DTM-25
- -data sheet for pressure gauge MS-200T
- -technical description and instructions for use of recording apparatus (KSP-4, PDS-021, PL-80), printing mechanism MP6-2
- -updated operations instructions of this instrument

The placement of the blocks of the complex "sonde-bathometer" on the ship depends on the convenience and security of overboard works, the reliability of the apparatus, and the rigging of the ship, its size and location of oceanological and hydrochemical labs.

When working with the bottle sampling section, there must be assured a correct transfer of sample water for which the work space must absolutely be safeguarded from splashes. When working at night it is also essential to illuminate the location of emergence of the sonde from the water and the location of placing the bathometer section on board ship.

The work areas (winches with sonde-bathometer and labs with on-board apparatus) are provided with a 2-way telephone connection, which allows, when essential, the correction of the tuning of the apparatus to conform with the conditions of sounding. With this goal in mind, there must be a good field of view from the lab to the winch with the sonde-bathometer.

The use of the complex "sonde-bathometer" includes 3 basic functions: ensuring the functioning of the apparatus of the complex, checking the reliability of the measuring gauges, and checking their calibrations and accuracy of observations.

The installation, operating the adjusting of the complex "sonde-bathometer" is accomplished by the specialists of Ts.K.B. GMP, with a two day control run of the apparatus in the port zone. Ts, K.B. also implements the tuning and calibration of the measuring channels after a routine voyage (when necessary) and teaching of fellow workers who are involved in the use of the apparatus on ships, by way of organizing courses of study at Ts.K.B. Ts.K.B. also gives essential technical documentation, assures the preparation and delivery of ZEP (standard seawater) and eliminates errors in the apparatus in mid-voyage stops.

The ship owner assures the preparation of ships for installation of the apparatus, "sonde-bathometer". Oceanographic teams make provision for the use of the apparatus, carrying out observation, eliminating errors which come up on the voyage and preparing the apparatus for routine voyages.

When working with the bottle section the taking of the sample is done by an oceanographer and their analysis by a hydrochemical team.

All measuring gauges must be provided with test documents. For the present, Ts.K.B. GMP provide testing only of pressure gauges.

Calibration of temperature and salinity gauges is done in field conditions. The method of calibration is given in section 3.1.

The readings are represented in various forms on the recording apparatus. Their calculation is possible on ships' computers about which more is written below in section 2.2. For calculation by hand, there are worked out some nomographs corresponding to the parameters being measured (specific electroconductivity, temperature, pressure, and salinity). The nomographs are also used in calibrating the electroconductivity gauges. By the results of the use of the complex, "sonde-bathometer" in voyage, the following materials are prepared; tables, lists, graphs, etc. The schedule and form of the materials under discussion are given in section 4.

## II. Conversion of read-outs of Sonde-Bathometer to Physical Parameters: Hydrostatic Pressure, Temperature and Salinity

The read-outs of the measurement gauges of sonde-bathometers are shown in decimal numbers on a digital display, on the printer, base-eight numbers on perforated tape, analog recording on KSP-4 and plotter PDS-021M. The transition to physical parameters is accomplished by the formulas given below.

### 2.1. Calculation Scheme

#### 2.1.1. Hydrostatic Pressure

Pressure gauges give as signal, a number $P_{dat}$ ranging from 0-2500. The value $P_{dat}$ must be corrected by correction $\Delta_i = f(Z_i)$ conforming to the calibration document by a linear interpolation formula

$$P = P_{dat} + \Delta_i \frac{(Z_i - P_{dat})(\Delta_i - \Delta_{i-i})}{(Z_i - Z_{i-i})} \qquad (1)$$

where $\Delta_i$ is the correction for depth $Z_i$ the definitions of the other two quantities are given above.

It must be taken into account, that the calibration document is made up at the factory and is checked out in expedition conditions (by the method described in section 3.1.)

2.12 Temperature

Temperature gauge t gives a signal, $t_{dat}$, which ranges from 0-4000. The value of t must be calculated by empirical formula:

$$t = a\, t_{dat} + b \qquad (2)$$

where a and b are empirical coefficients and are determined by calibration of the temperature gauge in field conditions (method described in section 3.1.)

2.13 Salinity

Electroconductivity gauge $E_{dat}$ ranges from 0-4035. The value of $E_{dat}$ must be calculated in electroconductivity by empirical formula:

$$E = aE_{dat} + b \tag{3}$$

where a and b are empirical coefficients and are determined under field conditions (method described below in section 3.1.3).

Further, the transition from value E to salinity uses the scheme and analytic expression worked out by V.E. Zaburdaev and P.A. Kalashnikov [1].

1) calculation of specific electroconductivity

$$X_{stp} = \frac{1}{aE_{dat} + b} \tag{4}$$

2) calculation of relative electroconductivity at pressure P.

$$R_{stp} = X_{stp}/X_{35,t,p} \tag{5}$$

where

$$X_{35,t;p} = X_{35,15,0} \cdot f(t) \cdot 1(p) \tag{5.1}$$

$$X_{35,15,0} = 42{,}895 \cdot 10^{-3} \tag{5.1.1}$$

$$f(t) = 0{,}6766 + 0{,}0200582 \cdot t + 1{,}09427 \cdot 10^{-4} t^2 - 0{,}634825 \cdot 10^{-6} t^3 \tag{5.1.2}$$

$$1(p) = 1 + 0{,}01[g(t) \cdot f(p) + h(p) \cdot 1(t)] \tag{5.1.3}$$

where

$$g(t) \simeq 1{,}5192 - 4{,}5302 \cdot 10^{-2} t + 8{,}3089 \cdot 10^{-4} t^2 - 7{,}9 \cdot 10^{-6} t^3$$

$$f(p) = 1{,}042 \cdot 10^{-3} p - 3{,}3913 \cdot 10^{-8} p^2 + 3{,}3 \cdot 10^{-13} p^3 \tag{5.1.3.2}$$

$$h(p) = 4 \cdot 10^{-4} + 2{,}577 \cdot 10^{-5} p - 2{,}492 \cdot 10^{-9} p^2 \tag{5.1.3.3}$$

$$1(t) = 1 - 1{,}535 \cdot 10^{-1} t + 8{,}276 \cdot 10^{-3} t^2 - 1{,}657 \cdot 10^{-4} t^3 \tag{5.1.3.4}$$

3) The reduction of rel. electroconductivity $R_{stp}$ to relative electroconductivity $R_{sto}$ at atmospheric pressure.

$$R_{sto} = R_{stp} + \Delta p \tag{6}$$

where $$\Delta p = -10^{-4}(1 - R_{stp}) \cdot 0{,}0412 p (1 - 0{,}03876 t + 0{,}0006122 t^2) \tag{6.1}$$

4) Reduction of relative electroconductivity $R_{s,t,o}$ to relative electroconductivity $R_{S,15,0}$ at temperature 15°C and atmospheric pressure P

$$R_{s,15,0} = R_{s,t,0} + \Delta_{15} \tag{7}$$

where

$$\Delta_{15} = 10^{-5} R_{sto}(R_{sto} - 1)(t - 15)\{103,7 - 86,6R_{sto} + 73,3R^2_{sto} - 24R^2_{sto}[0,63 + 0,21R^2_{sto} + 0,63f(R_{sto})]\cdot (t + 15) + 0,0244\cdot f(R_{sto})(t - 15)^2\} \tag{7.1}$$

where

$$f(R_{sto}) = 1,17 - 2,435R_{sto} + 6R^2_{sto} - 4R^3_{sto} \tag{7.1.1}$$

5) Calculation of salinity by relative electroconductivity

$$S = -0,08996 + 28,2972R_{15} + 12,80832R^2_{15} - 10,67869R^3_{15} + 5,98624R^4_{15} - 1,32311R^5_{15} \tag{8}$$

In the cited formulae (1-8) the units of temperature are scaled according to IPTS-68 (International Practical Temperature Scale, 1968).

In this way the conversion of readings of the gauges of electroconductivity E to the value of salinity may be provided by way of calculation by formulae (3-8) on the computer "Minsk-32 (22)", about which there is a detailed description in Section 2.2.

Salinity may also be defined graphically by Nomographs dependent on specific electroconductivity X from temperature T, salinity S, and pressure P. The nomograms are constructed on the basis of solution (5)-(8) and are shown in Appendix 2. They consist of 2 parts: in the first part (I) dependencies are constructed S = F(X,T) in the second part (II) the increase of specific electroconductivity at depth P is taken into account. The cited nomograms allow the determination of salinity in ranges from 20-40 °/₀₀, at temperatures from -2 to +30° to depths of 2000 m. In practice, not all graphic nomograms are used, only those which relate to the working ranges. Thus, for a chosen range, one can construct a working nomogram for which one must use the tables in Appendix 2, by which the nomograms are constructed. In the working nomogram is also incorporated the third part with the calibration of the electroconductivity gauge. An example of a working nomogram for range of salinity 34° - 38 °/₀₀, temperature 2-27° is given in figure 3.[a]

The accuracy of the determination of temperature, salinity and hydrostatic pressure depends on the reliability of the measuring gauges and the whole complex with the aid of corrections to the calibration. The scheme described above assumes a high accuracy of temperatures (to 0.02°C) salinity (0.05 °/₀₀) only subject to the reliability of the original parameters. The deviation of specific electroconductivity by 0.001 mho/cm causes a change of salinity of 0.7-1 °/₀₀, therefore, the specific electroconductivity must be defined especially carefully. A change of temperature when measuring electro-

a. Fig. 3 and the nomographs referred to are not available - transl. note.

conductivity causes changes in the measurement of salinity of almost the same numerical magnitude. The value of pressure evidently has an influence on the value of salinity, but not more than 2.5 - 10 $^{\circ}/_{\circ\circ}$, starting from a depth of 500 m.

2.2. Machine calculation of the result of profiling

For calculation on a computer it is essential to have at one's disposal: (1) program (2) a data block and program for the reduction of sonde-bathometer readings (3) results of profiling.

2.2.1. Brief characteristic of program

The program provides for processing on the computer "Minsk 22" or the computer "Minsk 32" (with a compatable interface) of perforated tapes with the results of profiling.

The processing of the data is carried out for each sequence of data. At first, the incoming data is monitored for the beginning of the data sequence signified by the appearance of a negative reading followed by the collection of parameters in the data sequence. Spurious dataare thus automatically excluded. Further, a conversion is performed from what the gauges show, to the physical parameters: from what the temperature gauge shows $t_{dat}$ to temp t (by formula 2); from what the pressure gauge shows $P_{dat}$ to depth P (by formula 1); from what the electroconductivity gauge shows $E_{dat}$ to specific electro-conductivity X by formulas (4) - (8) the salinity S is calculated, and thus conditional specific gravity $\sigma_o$ density $\sigma_t$ and specific volume $V_t$.

2.2.2. Preparation (punching) of Data Block with working information about the sonde-bathometer

1. In Base 8 code ATsPU information is punched giving name of ship and number of voyage.

| Address | Code | | | | Example |
|---|---|---|---|---|---|
| 10010 | 55 | 50 | 6157 | 1717 | NISP |
| 1 | 74 | 60 | 5561 | 6217 | ERNST |
| 2 | 52 | 60 | 4555 | 5245 | KRENKE |
| 3 | 53 | 73 | 1722 | 0203 | L (23 |
| 4 | 06 | 23 | 1717 | 1717 | 6)---- |
| 5 | 17 | 17 | 1717 | 1717 | ------ |
| 6 | 10 | 17 | 6045 | 5161 | 8 VOYAGE |
| 7 | 17 | 57 | 5653 | 7452 | POLEX |

2. In decimal code with code comma, coefficients a & b are punched for dependency (2) & (3), which are obtained on calibrating the measuring gauges.

| Address | Code | Example |
|---|---|---|
| 10030 | +0,0971 | $E = 0,971E_{dat} + 13,271$ |
| 1 | +132,71 | |
| 2 | +0,0087 | $t = 0,0087t_{dat} + 4,75$ |
| 3 | +4,75 | |

MODEL 1

Configuration of information of sonde-bathometer on punched tape at recording of the four parameters in one scan.

"end"

| | | | | |
|---|---|---|---|---|
| $-E_{dat}$ | $t_{dat}$ | $P_{dat}$ | N. | first scan |
| $-E_{dat}$ | $t_{dat}$ | $P_{dat}$ | N. | second scan |
| | | | | |
| $-E_{dat}$ | $t_{dat}$ | $P_{dat}$ | N. | last scan |

"end"

MODEL 2

Configuration of information of sonde-bathometer on punched tape at recording of the three parameters in one scan.

"end"

| | | | |
|---|---|---|---|
| $-E_{dat}$ | $t_{dat}$ | $P_{dat}$ | first scan |
| $-E_{dat}$ | $t_{dat}$ | $P_{dat}$ | second scan |
| | | | |
| $-E_{dat}$ | $t_{dat}$ | $P_{dat}$ | last scan |

"end"

Legend

"--" - Machine Base 8

" . " - Machine code

$E_{dat}$, $t_{dat}$, $P_{dat}$ - Base 8 number equivalent shown on gauges salinity, temp., pressure, respectively

"N" - number of bottle of bathometric section.

MODEL 3

| | |
|---|---|
| "end" | |
| no. of voyage | +8 |
| year | +1974 |
| month | +11 |
| date | +19 |
| time of start | +21 |
| time of finish | +21.6 |
| width of start | +55.7 |
| length of start | +47.1 |
| width of end | +55.9 |
| length of end | 47.8 |
| no. of station | +21 |
| no. of series of sonding | +2 |
| depth of sea | +1235 |
| no. of bathometer in section | +5 |
| quantity of parameters in one scan | +4 |
| "end" | |

3. In decimal code with code comma are punched the certificate data of pressure gauges.

| Address | Code | | | Example |
|---|---|---|---|---|
| 10034 | 0011 | 0000 | 0000 | |
| 5 | +0 | | | |
| 6 | +200 | | | |
| 6 | +234 | | | Value of pressure P from certificate |
| 7 | +393 | | | |
| 10047 | +2032 | | | |
| 10050 | +0 | | | |
| 1 | +0 | | | Corrections from certificate relating to P |
| 2 | +10 | | | |
| 7 | -7 | | | |
| . | . | | | |
| . | . | | | |
| 10057 | +16 | | | |

The processed data are printed by means of printer EVM-ATsPU in the form of tables (Appendix 1, table 5).

The program is machine coded for the Minsk 22 and entered into the first partition of the operational memory from locations 0100 to 5600. The data from the profile is then entered into the second memory partition starting at location 0100. Information on the working of the sonde-bathometer is then brought into the second partition in location 0000-0077. The data is then processed one sequence at a time and printed out line by line. The processed results are not kept in the memory.

2.2.3. Preparation of Sonding Results

The results of the sonding consist of 2 "data blocks": one is brought in automatically on the PL-80 during sonding - the results of measurements; the second is perforated by hand and contains the information about the place and time of observation. The models of the data blocks are given earlier (Model 1, Model 2).

The preparation of the information for processing on the computer consist of the following operations:

1) perforated tape from the PL-80 is taken off and its quality is checked (the defects in the paper, the position of the perforated track);
2) the perfo-tape is placed on a re-perforating machine, the pre-data information of the data block is punctured, a re-perforation of tape, which was taken off the sonde-bathometer is done; the post-data information of the data block is punched.
3) A leader 10-15 cm long is punched on the perfo-tape, the pre-data information of the second data block is punched, a data block in decimal code with a comma is perforated following Model #3, the post data word of the second data block is punched on;
4) At the beginning and end of the tape is written: the name of the ship, the number of voyage, date, time, no. of station, and sonde-bathometer number.

2.2.4. Processing on computer (Instructions to the Operator)

The program works in the Minsk-22 computer schedule, ATsPU and FSU is used.

1) To read-in the program
2) To introduce the data block with the working information about the sonde-bathometer.
3) To set up the original data on the FSU as in Model 1 or 2 for data block 1, and as in Model 3 for data block 2.
4) Start - 122.

Base data will be introduced and on the ATsPU, table 5 from Appendix 1 will be printed line by line.

5) Stop - 0427.
6) While processing the next execution start - 132. After printing of table Stop - 0427.

2.3. The Manual processing of sonding results

For the manual processing the following is used:

1) A number printer (which is introduced on the PM-16-2 device), where the results of the gauges are printed line by line in the following sequence:

| | | | | |
|---|---|---|---|---|
| $E_{dat}$ | $t_{dat}$ | $P_{dat}$ | N | 1st line |
| $E_{dat}$ | $t_{dat}$ | $P_{dat}$ | N | 2nd line |

The fourth parameter N, the no. of the bathometer can be missing.

2) calibration tables of graphs, composed on the basis of the factory calibration in the manual or else on the basis of the calibration of the gauges in expedition conditions obtained by the method described in section 3.1.
3) Nomographs from Appendix 2 or the working nomograph drawing #2. Examples of sonding results are shown in table 5, Appendix 1.

On the top part of the table, information that is common to all the sonding results on this particular station are written:

-In the first line - the name, code no. of ship, voyage number, and name of ocean (c);

-In the second line - the year, month, day and time of the beginning and end of the sonding, corrdinates (latitude and longitude) of the beginning and end of sonding;

-In the third line - the number of station and depth;

-In the fourth line - the calibrating coefficients a and b for the linear relationship $t = f(t_{dat})$

-In the fifth line - the same for $E = f(E_{dat})$. Into column 1-4 of the printer output are typed the values of N, $P_{dat}$, $t_{dat}$, $E_{dat}$.

-Into columns 5-7 are typed the corrected values for P, t, x, correct according to the calibration tables or calibration graphs.

-The values of salinity, which are defined by t, x, and P from the nomograms from Appendix 2 are typed in column 8. The key to the usage of the nomograms is given in the description of the nomograms.

In the table, column 9 and 11 are also taken into consideration; into which the calibrated values of the nominal specific gravity $\sigma_o$, the nominal density $\sigma t$ and the nominal specific volume $V_t$ are calculated during the machine processing.

All data from the profile can be printed in the table or else only the part for depths for every 10 or 50 or 100 (etc) meters as well as for the depths of light gradients and extremities.

3. Contents and order of work with the sonde-bathometer complex

Work associated with the complex is composed of: the calibration of the measuring gauges of the sonde-bathometer; the production of observations; servicing of the apparatus of the complex.

3.1. Calibration of Measuring Gauges

Calibration of the measuring gauges in field conditions is done by comparing $x_i$; the sonde-bathometer readings and readings of standard instruments $y_i$; at control points.

As a standard during the calibration of the pressure gauges the documented calibration constants of the DTM-25 and the MD-200t are used.

The readings of the temperature gauge are compared with readings of deep-sea thermometers attached to the bathometric section of the lowering container.

The calibration of the salinity gauge is done by comparing the sonde-bathometer readings of salinity and the results of the laboratory determinations of salinity at the control points taken by the bathometrical section.

On the basis of the comparison of rows $x_i$ and $y_i$ an equation of the form $y = ax + b$ is put forth along the following scheme. The equation in the form of a deviation from the average may be written

$$\frac{y - y_{cp}}{x_i - x_{cp}} = r \frac{\sigma y}{\sigma x}$$

OR

$$y = r \frac{\sigma y}{\sigma x} x_i - \left( r \frac{\sigma y}{\sigma x} x_{cp} - y_{cp} \right)$$

FROM WHICH

$$a = r \frac{\sigma y}{\sigma x} \tag{9}$$

$$b = r \frac{\sigma y}{\sigma x} x_{cp} - y_{cp} \tag{10}$$

$$r = \frac{\Sigma (x_i - x_{cp})(y_i - y_{cp})}{\sigma_x \cdot \sigma_y \cdot n}$$

WHERE $x_{cp} = \frac{\Sigma x_i}{n}$ $y_{cp} = \frac{\Sigma y_i}{w}$

$$\sigma_x = \sqrt{\frac{\Sigma (x_i - x_{cp})}{n}} \qquad \sigma_y = \sqrt{\frac{\Sigma (y_i - y_{cp})}{n}}$$

The calculation of coefficients a and b in the compared rows $y_1$ and $y_2$, $y_3$.... can be done on the on-board computer (on the regressional analysis program) or obtained by graphically comparing rows x and y (which is recommended when the ship is not equipped with a computer).

The results of the calibration are written into the tables in the form of Tables 1 - 3 from Appendix 1. The choosing of control material is done throughout the whole length of the voyage. Control data not used in the calibration is checked against the corrected data. The deviation from the control results with a calculated value shouldn't be more than: in temperatures ± 0.02°C in salinity ± 0.05 °/₀₀.

3.1.1. The Calibration of the Pressure Gauges

The data from the gauge certificate of range I (from 0-200 m) are checked against the meter wheel reading and the length of the marked cable. The second range gauge (200-2000 m) is checked with the help of a temperature depth gauge. The first range gauge is checked in steps of 10 meters.

The calibration of the second range pressure gauge is done against the readings of the control temperature-depth gauges in steps of 20 meters with small (up to 20°) cable angle. If the factory calibration of the second range pressure gauge is confirmed in 4-5 points by the temperature-depth gauges, then it is accepted as the working calibration with subsequent regular checks of the data with the temperature-depth gauges.

The measured values of the pressure in decibars ($P_{dat}$) are recalculated into pressure (P) against the accepted calibration table with the aid of a linear interpolation.

$$P = P_{dat} + \Delta_i \frac{(Z_i - P_{dat})(\Delta_i - \Delta_{i-i})}{(Z_i - Z_{i-i})}$$

where Z (pressure) and Δ (correction) are taken from the depth gauge certification.

3.1.2. Calibration of Temperature Gauge

In the process of sonding, layers are uncovered with uniform vertical distribution of temperature of a thickness of 30-50 meters. Then when lifting the sonde, the temperature is taken sequentially from each of the layers found. Over a period of 5 - 7 minutes at each level, the temperature is recorded on the paper tape and on the character printer. If in the period of this measurement the temperature doesn't change or if its changes are not greater than ± 0.01°C, then on the given level, on the command of the operator, the 3 bathometers (bottles) are closed and four deep water thermometers are tipped. In this way, in one sonding there may be obtained 3-4 completely reliable points for calibration of the temperature and salinity gauges.

The readings of the deep water tipped thermometers and temperature-depth gauges are processed by methods generally accepted by oceanographic practitioners.

For the accuracy of the temperature value on the level, the average temperature is accepted over four values, if the difference among them is not greater than 0.05°C.

A series of paired values of temperatures obtained in this manner and readings of the sonde are plotted on a graph for a preliminary analysis (by axis ordinate - value of temperature, by axis abscissa - reading of sonde).

The equation of correlation has the form: $t = at_{dat} + b$ where $t_{dat}$ - reading of sonde by channel of temperature, a, b - coefficients of equation of regression.

By the obtained points is constructed the correlation graph. All subsequent points of comparison of data are plotted on this graph; in the case of disagreement from the line by more than ± 0.02°C, the reliability of the temperature gauge comes under question. The points for calibration must cover the specified range of temperatures, including extreme values.

3.1.3. Calibration of Salinity Gauge

For calibration of the salinity gauge, samples are taken from the bathometric (bottle) section corresponding to the experimental data used to calibrate the thermometer. Further, five operations are carried out:

1) The control value of salinity is defined as the average value from P - samples (not less than three), taken simultaneously at a given level, and called $S_{lab}$, by relative electroconductivity on the "lab" salinometer GM-65. The control value is counted to be reliable if the difference between the extreme values on the given level does not exceed 0.01 °/₀₀.

2) Further, by the nomographs of Appendix 2, Part 1, the salinity, $S_{lab}$, is converted to a value of electroconductivity $X_{sto}$ with the stipulation p = 1 atmosphere and temperature, that at which was determined the salinity in laboratory, $t_{lab}$ [a] (sic).
3) Value $X_{sto}$ comes to condition p, for which is used the second part (II) graph nomogram. Value $\frac{1}{x_{stp}} = E^1$ is taken as value $y_i$.
4) Value $E_{dat}$ on level taken from test (sample) is taken as value $x_i$.
5) Graphically, or by formulas (9), (10) an equation is produced linking $E = aE_{dat} + b$.

Samples from following profiles should follow the above straight line regression. Departures from the straight line regression should not exceed 0.05°/₀₀.

3.2. Processing Observations

Observations with the aid of the sonde-bathometer include the following basic operations:

-preparation of apparatus for profiling;
-writing on recording tapes (perfo-tapes, character printer) and in the field journal a review about the place and time of profiling;
-starting up the apparatus, lowering and raising the container and measuring gauges;
-starting up the apparatus, the raising of the lowering device on board ship;
-processing the results of profiling and formulating the documentation under discussion.

For carrying out the work with the sonde-bathometer there are employed personnel who have gone through special technical preparations. A full cycle of observations takes two operators: both operators are needed to take out the lowering device aboard ship. From the moment of its lowering, one operator assures the operation of the winch - the second observes the work of the sonde and recording apparatus. Then both operators lift the lowering device on board and process the results.

Profiling with the aid of the sonde-bathometer may be accomplished from the ship, either adrift or at anchor, in one of the given regimes: Vertical sonding (single or multiple) or prolonged measurement at one level.

3.2.1. Order of Work with the Probe

1) The lowering device with the bathometer section is looked over; the cable winch, the on board apparatus, and the pressure seal fasteners are checked.
2) Calibration is completed of the recording device by channels of electroconductivity, temperature, and pressure.
3) With the help of a winch cable and single-rail overhead travelling crane (cathead) the lowering device and bathometer section are reeled out from on board and are sunk to a depth of 1 - 1.5 meters, such that in the pressence of sea waves the gauge would

a. Probably should be $t_{in\ situ}$ - transl. note.

not break the surface. In this situation the lowering device will not read the water temperature until its body nears equilibrium with the water. (2-3 min. or at large air-water difference, up to 30 min.)

4) On the graph paper of the chart recorder and the perforated tape is indicated date, no. of station, depth of sea and other information, shown in Model 3.

5) The indicators of the meter wheel counter at that length of paid-out cable are set at zero point, after which at the start of vertical profiling the on-board apparatus is turned down and a lowering is done to the required depth, but not more than 2000 m. The speed of lowering must not exceed 1 m/sec, and in layers with temperature gradients 0.05 - 0.1 degrees/meter and higher, not more than 0.4 m/sec., so that on the segments of maximal gradients the speed of lowering would be minimal, and on the segments with minimal gradients - maximum. The lowering must be done with a regular or irregular speed, and regular or steady speeding up or slowing down.

For the prolonged measurement at one level the on-board device is activated after reaching level of measurement.

6) The lifting up of the sonde is made ready. On graph paper and punch tape the time of the lifting of the sonde is recorded.

When working in the regime of vertical profiling, the levels of sample taking of seawater are outlined with the aid of the bathometric section. The lift is initiated on the command of the operator of the panel. The control is accomplished on the actuation of the sequential bathometer and the recording of the parameters on the recording apparatus is completed and the lifting continues to the next level. The speed of lifting must not exceed 2-2.5 m/sec. After lifting to a depth of 100 meters, the speed is decreased to 1-1.5 m/sec., and after 10 meters or the signal "that she blows" the speed should be slowed to a minimum and the recording devices should be shut off.

For prolonged measurement at one level, the on-board recording devices are shut off before lifting.

7) After the sonde has been lifted on board and recording devices have been shut off, the sonde and bathometric section are mounted in initial approach position.

8) The data block of Model 3 is punched by hand. The punched tapes are transmitted over to be worked over on the shipborne computer (see section 2.3).

3.2.2. Features of Operating Conditions of Profiling

Station OGSOS, bathythermographic observation, deep sea stations, sectional views and stations taken on a random basis are completed in the "one-time profile" mode of operation of the sonde. Calibration of the measuring gauges is carried out also in the condition of vertical sonding with stops at fixed levels of 5 - 7 minutes.

For the measurement of temporal variability of the profiles of temperature or salinity, the variability of the fine structure of the profile and the recording of internal waves, a time series of profiles is taken over regular intervals of time and pre-chosen intervals of observation. (e.g., over 1-2 hours over a lapse of several days).

The time taken for one sonding is determined by the thickness of the layer under study and the speed of lowering and raising of the sonde. For this it is essential for all sondings to have the same speed of lowering $V_{lower}$ and raising $V_{raise}$.

$$\theta_3 = \frac{\ell}{V_{lower} + V_{raise}} + \theta preparation$$

where $\theta_{preparation}$ -- time of preparation of registers to the new sonding,
$\ell$ - length of played out cable.

The formulation and processing of materials for multiple sonding is done for each time series.

In a mode of prolonged measurements on one level, used for study of time-dependent variability of temperature and salinity at a given depth, the choice of segments of depths of measurement is selected according to the character of a curve; taken earlier by vertical profiling (or by given voyage program).

For eliminating the influence of drift of the ship on the measurement of depth, truss-cable is played out in addition to the length needed to reach the required depth. Because of the variability of speed and direction of the ship's drift, the sonde "takes a walk" at that depth, and thus it is essential to keep a check on the depth indicators and, with the aid of the winch, to hold it steady within (1-2) m.

The duration of observations at one level is determined by the requirements of the problem. Before proceeding, one must keep in mind that the high frequency part of the spectrum of the measured quantities is distorted by "noise" generated by the measuring gauge and the movement of the sonde in the depths from the rocking of the ship; the low frequency part is bounded by half the period of observation. From this we can see that the period of observation ($\theta_{obs}$) must not be less than 10 $T_k$ where $T_k$ is the period of the roll of the ship.

3.3. Care of the Apparatus of the Complex

To ensure the proper operation of the complex, the following instruments are necessary:

1. Tester TS-4315
2. Oscilloscope type C1-19, C1-49
3. Resistance Box type MSR-60

In the course of the voyage, the instrument engineer ensures the control and correct adjustment of the measurement channels, carrying out of preventive maintenance and repair of the apparatus if it should go out of order.

4. Review of Materials

As a result of using the sonde-bathometer complex at sea, the following materials are produced:

1) a list of profiles with notes on the conditions at the time of profiling in the form of Table 4, Appendix 1.
2) Tables of calibrations performed on the gauges 1-3, Appendix 1.
3) Tables of processed data of the sonde-bathometer (Table 5, Appendix 1)
4) Punched tape of profile results.
5) Print-out of profile results.

Given the reliable operation of the sonde-bathometer, Table TGM-3 is formed based on the data listed in Table 5, Appendix 1 or based on data taken from the print-out of profile results.

## APPENDIX 1

### Samples of Material Under Discussion

TABLE 1

Results of Verification of Pressure Gauges

| Range I of depth | | | | Range II of depth | |
|---|---|---|---|---|---|
| Pressure from the Sonde-Bathometer Table | Certificate Correction | Pressure of Sonde-Bathometer with Corrections | Length of Marked Cable | Depth by block Calculator | Reading of Thermodepth Measure |
| 0 | 0 | 0 | 0 | 0 | |
| 10 | 0 | 10 | 11 | 10.1 | |
| 20 | -5 | 15 | 27 | 20.2 | |
| 30 | -10 | 20 | 41 | 20.7 | |
| 40 | 2 | 42 | 40 | 41.2 | |
| 50 | 1 | 51 | 48 | 50.0 | |
| -- | -- | -- | -- | -- | |
| -- | -- | -- | -- | -- | |
| -- | -- | -- | -- | -- | |
| 200 | -1 | 199 | 211 | 199.5 | |
| 220 | 2 | 222 | | | 219 |
| 240 | -7 | 237 | | | 240 |
| 260 | 16 | 276 | | | 274 |
| 280 | -19 | 261 | | | 260 |
| 300 | 15 | 315 | | | 310 |
| -- | -- | | | | -- |
| -- | -- | | | | -- |
| -- | -- | | | | -- |

TABLE 2

Calibration of Temperature Gauge

| No. | Data Calibration (sonding) | Level (P) | Gauge Z - b | Depth Temp. | Δ | Comments |
|---|---|---|---|---|---|---|
| 1 | 25.02 | 1546 | 10.05 | 10.05 | 0.00 | |
| 2 | 26.02 | 1684 | 11.26 | 11.23 | -0.03 | |
| 3 | 27.02 | 1684 | 11.26 | 11.23 | -0.03 | |
| 4 | 29.02 | 1769 | 12.00 | 12.07 | 0.07 | |
| 5 | 1.03 | 1903 | 13.18 | 13.20 | 0.02 | |
| 6 | 7.03 | 1904 | 13.19 | 13.22 | 0.03 | |

Equation: $t = 0.008768t_{dat} + 3.51$; $R = 0,999$; $\sigma = 0,009$.

TABLE 3

Calibration of Electroconductivity Gauge

| No. | Data of Sounding | Data of Trials Taken W/Aid of Bathometric Section | | Data of Trials Taken W/Aid of Sonde-Bathometer | | $E_{3-6}$ | Comments |
|---|---|---|---|---|---|---|---|
| | | $S_{lab}$ | $t_{lab}$ | $E_{dat}$ | $t_{dat}$ | | |
| | 29.03 | 35.157 | 23 | 511 | 19.51 | 3255 | |
| | | 34.986 | 23 | 509 | 19.62 | 3266 | |
| | | 35.153 | 21 | 490 | 20.24 | 3328 | |
| | | 35.076 | 29 | 510 | 19.52 | 3256 | |
| | 30.03 | 35.148 | 23.5 | 517 | 19.26 | 3232 | |
| | | 35.130 | 16.5 | 444 | 22.51 | 3556 | |
| | | 35.176 | 20 | 479 | 20.86 | 3392 | |
| | | 34.302 | 21 | 487 | 20.45 | 3352 | |

R = 0,99831
σ = 0,0118
E = 0,01019E +18,03792

TABLE 4

List of Sonding of Ocean
With Complex "Sonde-Bathometer" in
9th Voyage NI Sp. E. Krenkel, 1975

| No. | Data, Greenwich Time Sonding, Hours, Mins. | | No. of Station | No. of Sonde | Depth of Sonding | Conditions of Work |
|---|---|---|---|---|---|---|
| 1 | 21.02 | 7.40 | 6 | 06 | 300 | The pressure sealing signal "water" is broken |
| 2 | 22.02 | 18.50 | 9 | 06 | 600 | |
| 3 | 22.02 | 18.50 | 9 | 02 | 600 | |
| 4 | 23.02 | 12.45 | 11 | 06 | 250 | |
| 5 | 23.02 | 12.45 | 11 | 02 | 250 | |

TABLE 5

Example of Recording and
Processing of Data from Sonde-Bathometer

NISP, Ernst Krenkel (236) 9 voyage, Ocean - Atlantic
Year 1975, Month 3, Date 13
Time 11:30-12:30, Coordinates 65.10, 8.26, 65.10, 8.26.
No. of Station 77, Depth 1110 m.
Calibration coefficients: Temperature, Electroconductivity

| a | B |
|---|---|
| 0.008 | 3.51 |
| 0.01019 | 13.04 |

| No. | $P_{dat}$ | $t_{dat}$ | $E_{dat}$ | N | t | X | S | Specific Gravity $\sigma_o$ | Density $\sigma_t$ | Specific Volume $V_t$ Parameter |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 4 | 555 | 2109 | 0 | 1.36 | 0.029399 | 34.6045 | 27.8076 | 27.7262 | 73.0218 |
| 0 | 7 | 556 | 2110 | 4 | 1.37 | 0.029391 | 34.5803 | 27.7881 | 27.7062 | 73.0408 |
| 0 | 6 | 555 | 2110 | 5 | 1.36 | 0.029391 | 34.5922 | 27.7977 | 27.7163 | 73.0311 |
| 0 | 4 | 555 | 2109 | 5 | 1.36 | 0.029399 | 34.6045 | 27.8076 | 27.7262 | 73.0218 |
| 0 | 4 | 555 | 2109 | 6 | 1.36 | 0.029399 | 34.6045 | 27.8076 | 27.7262 | 73.0218 |
| 0 | 9 | 555 | 2111 | 7 | 1.36 | 0.029382 | 34.5799 | 27.7878 | 27.7065 | 73.0405 |

## APPENDIX 2

Nomograms Corresponding to Salinity S, Temperature t, and Specific Electroconductivity X.[a]

Nomograms are constructed on the basis of analytical expressions developed by V.I. Zaburdaev and P.A. Kalashnikov and are presented in five diagrams. In each of them are presented direct links between salinity and specific electroconductivity for different values of water temperature S = f (X,t). For calculating the increase of specific electroconductivity with depth the nomograms are combined with the graphs of x = f(H) (straight lines, drawn on top-to bottom-to the right).

With the aid of the nomograms, it is possible to define salinity by measurement of in situ parameters (x,t,p). The resolution in the determination of S is 0.03 °/₀₀, the nomograms allow us to also solve the reverse problem: by the known value for salinity S to define the value of specific electroconductivity X. The resolution in the determination of X is 0.003 $om^{-1}cm^{-1}$. Use of the nomograms is shown on Figures 4 & 5 by the examples below.

A) Determination of Salinity
Original data:
Specific electroconductivity X = 0.038 $om^{-1}cm^{-1}$
Temperature t = 10.5°C
Depth H = 1500 m.

1) On Fig. 4 is found point A by the given value X (0.038) and H (1500).
2) Across point A a line is drawn, parallel to the closest line expressing S = f(H) to intersect with the top level axis x.
3) From the point of intersection drop a vertical value of temperature (10.5°C) i.e. point $A^1$.
4) For point $A^1$, the left vertical axis S gives the unknown value of salinity, 33.75 °/₀₀.

B) Determination of Specific Electroconductivity
Base data:
Salinity S = 35.15 °/₀₀
Temperature t = 13.00°C
Depth H = 1750 m.

Definitions:
1) On Figure 5 is found point B by the given values S (35.15) and t (13).
2) From point B a vertical line is drawn upward to intersect with horizontal axis x.
3) From point of intersect a line is drawn parallel to nearest straight line X = f(H): for the ordinate corresponding to depth 1750 m, point $B^1$ is found.
4) For point $B^1$, the horizontal top axis x gives the unknown value of specific electroconductivity - 0.04178 $om^{-1}cm^{-1}$.

a. Nomograms are not available - transl. note.

## LITERATURE


1. Zaburdaev, V.I., Dobruskina, A.M., Lyashenko, E.F., Poplavskaya, M.G. One of the methods of defining salinity by specific electroconductivity, temperature and pressure of seawaters. Report of MGI AN Ukrainian Soviet Socialistic Republic, 1970.

2. Prokhorov, V.I., Fedorov, K.N., Volchkov, A.G. Test of calibration of automatic thermosalinity sonde "Stork" in expedition conditions. Oceanology 3, 1973, Science Publications.

3. Contemporary methods and apparatus for measuring basic hydrological parameters. Comtemporary apparatus for oceanographic research (survey). Ed. MGI UN Ukr. Sov. Soc. Rep., 1970.

4. Fedorov, K.N., Formulas for converting electroconductivity of seawater into salinity when measurements are taken with digital CTD's in average ocean conditions. Oceanology 4, 1971. Science Publications.

5. Fedorov, K.N., Prokhorov, V.I. On the effect of time constants of temperature measurements and the reliability of the calculation of salinity in the ocean with the aid of CTD's. Atmospheric and Oceanic Physics, Vol. 8, No. 9, 1972. Science Publications.

6. Fedorov, K.N., Plakhin, E.A., Prokhorov, V.I., Sedov, V.G. The peculiarities of thermo-haline stratification in the region of the polygon in the Tropical Atlantic. Atlantic hydrophysical polygon - 70. Science Publications, 1974.

7. Horne, R. Marine Chemistry (p. 362 363), 1972.

8. International Oceanological Tables 1. Hydrometric Press, 1969.